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Research Project:

**MIXING, NOISE AND THRUST BENEFITS
USING CORRUGATED DESIGNS**

PERFORMANCE REPORT-98

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I. INTRODUCTION

This project was conducted under a NASA FY 1997 Partnership Award (1997-99), NAG-1-1936 as a support for effective research, training and teaching of Hampton University students in Fluid Mechanics and Acoustics. Basically, this work is organized and implemented by the new Fluid Mechanics and Acoustics Laboratory (FM&AL) which was established at Hampton University in the School of Engineering and Technology (E&T) in 1996. The initiation of this laboratory was made possible by NASA grant NAG 1835 (3 year FAR Award, 1996-99). In addition, FM&AL in cooperation with NASA LaRC jointly conducts research with the Central AeroHydrodynamics Institute (TsAGI, Moscow) in Russia under a 2 year Civilian Research and Development Foundation (CRDF) grant #RE2-136 (1996-98). This project is also conducted under control of NASA HQ.

For fulfillment of the current project, several researchers were involved as was shown in the proposal to NASA in 1996. This work is the development and support for another research effort under NASA grant NAG-1-1835, as both projects solve similar problems with the goal of reducing jet noise and increasing nozzle thrust. Thus, the current performance report content is similar to the performance report for the NASA grant NAG-1-1835, which was presented recently in June, 1998.

II. STATEMENT OF THE PROBLEM

Three main problems are investigated and developed under existing joint NASA/JNL and HU/FM&AL research programs:

1) Aircraft Engine Technology; 2) Aircraft Technology, and 3) Rotorcraft Technology. This research is conducted in close cooperation with US Aerospace professionals at Boeing, McDonnell Douglas, GE Aircraft Engines and Pratt & Whitney Aircraft, and specialists from Russian first class aviation and educational institutes: Central AeroHydrodynamics Institute (TsAGI, Moscow and Zhukovsky), Moscow State University (MSU), Institute of Mechanics at MSU (IM/MSU) and others. In addition, several applied problems for domestic industry are also studied using knowledge and experience from Aerospace Sciences.

The reduction of aircraft engine noise is a significant driver in the success of the NASA AST and HSR programs as they attempt to meet stringent international environmental regulations on noise for commercial aircraft. In accordance with the project fulfillment under this NASA grant, the FM&AL investigates novel and promising concepts for reduction of noise and improvement of propulsion efficiency in jet exhaust nozzles and fans.

Promising Exhaust Nozzle Concepts. Based on prior research studies conducted by Drs. Gilinsky and Seiner, a new method has been developed which permits the design of jet exhaust nozzles with optimized thrust while achieving jet noise reduction. This method led to the conception of the Bluebell, Chisel, and Telescope nozzles and to nozzles with Screwdriver-Shaped Centerbodies ([1,2,5-9]). Preliminary results are very interesting to the industry, but require further analysis and testing. The experiments, theory and approximate numerical approach to such designs are very convenient tools for introducing students to Fluid Mechanics, Gas Dynamics and Acoustics. The current research is focused on using the further development of these nozzle designs as a tool to interest undergraduate students in science, mathematics

and engineering. Real world applications seem to have a stimulating effect on the learning process.

A Möbius Strip Concept. In addition to the innovative nozzle designs, a Möbius Strip concept has been developed to improve the working efficiency of propellers and screws. A Möbius Strip is nothing more than a surface having only a single side which a student can readily produce from a strip of paper. The main idea of the invention [3] is to manufacture fans by rotating the Möbius Strip in order to reduce the rotated element drag and simultaneously to increase the area for capture of the still medium without increasing the power needed for rotation. This concept has been proposed as the basis for optimally shaped airplane and boat propellers, fans, helicopter rotors, mixing screws, coffee grinders, and concrete and paint mixers. Many industrial companies are interested in this invention and have agreed to participate in funding the research, development and joint marketing after further testing. At this time, only simple and inexpensive tests have been conducted. Several Möbius shaped screws have been built and tested for the mid-size class of household mixers. Tests have shown that a mixer with a Möbius-shaped screw pair is more efficient and saves more than 30% in electric power when compared with the standard model. A video film of these tests has been produced which can be used to introduce students to the concept of mixing and for commercial demonstrations. Further testing of this concept can also be used to involve undergraduate students in a real-world technology development project. The concepts involved are well within their capabilities. These designs were proposed and investigated by FM&AL and NASA LaRC researchers ([1-10]), and will be improved and optimized with HU students using current and future funding.

III. THE MAIN CURRENT RESULTS

The main achievements for the reporting period in the development of the concepts for reduction of noise and improvement in efficiency for jet exhaust nozzles for aircraft engines and screws for mixers, fans, propellers and boats are as follows:

a) Presentation of two papers at the 4th AIAA/CEAS Aeroacoustics Conference, June 2-4, 1998, Toulouse, France, ([4,5]), which described our concepts and some new results.

b) A Young Investigator Program Award (March, 1998) for support of the 2 year CRDF (Civil Research and Development Foundation) grant, #RE-136, with Hampton University (HU) and Central Aerohydrodynamic Institute (TsAGI, Moscow, Russia). This grant supports the research implementation under the existing NASA FAR grant.

c) Preparation and submission of two proposals for the NASA PAIR and NSF CETP Programs (no funding).

d) Meeting and joint experimental tests at the TsAGI, Moscow, of several NASA Bluebell nozzle designs and nozzle with Screwdriver shaped and axisymmetric centerbodies. Preparation of joint reports (November, 16-23, 1997).

e) Numerical simulation and comparison of theoretical with experimental results, modification of grids and theoretical models for several complicated 3D nozzle designs. Numerical simulations were conducted using NASA codes based on full Euler and Navier-Stokes solvers, CFL3D, CRAFT, and others.

f) Creation of an analytical model for optimization of a Möbius shaped screw for improving mixing efficiency and numerical estimations for several models.

g) Agreement with the TsAGI (Zhukovsky) to conduct jointly the project "Methods of the Nozzle and Jet Noise Reduction by the Dispersed Drop Screen".

IV. CONCLUSIONS

This project already benefits NASA and HU because:

1) the corrugated nozzle concept including several innovative designs, i.e. Bluebell, Chisel, Telescope and others, is an important item in the HSCT and AST Programs, which JNL implements jointly with well known aviation companies;

2) a Möbius Strip concept allows the use of the financial potential of some big domestic industrial partners for support and development of NASA and HU initiatives:

3) The joint theoretical and experimental research and training by the LaRC-HU Teams aids: using advanced methods and experience in Aerospace Engineering for domestic industries and training of HU students for interesting innovative work in the numerical simulation field and engineering and experimental research. HU students use and modify existing LaRC numerical codes for the solution of actual applied problems.

Our near future plans include the development of this research project for attracting more HU students in the project fulfilment, applications for additional funding by different agencies (NSF, ARO, AFOSR, ONR etc.) which will support all current FM&AL projects, and to elevate the status and facilities of the FM&AL at Hampton University such that HU students could conduct experimental and numerical tests at the HU campus solving modern applied problems in Fluid Mechanics and Acoustics.

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